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(54) **VALVE POSITIONER WITH OVERPRESSURE PROTECTION CAPABILITIES**


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***G05D 16/20*** (2006.01)

(52) **U.S. Cl.**
CPC ........ ***G05D 16/202*** (2013.01); *Y10T 137/0379* (2015.04); *Y10T 137/7761* (2015.04)

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See application file for complete search history.



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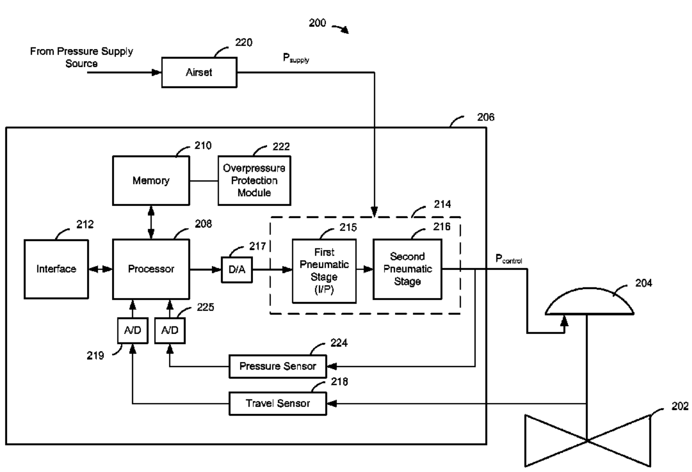
(57) **ABSTRACT**

A method of limiting control pressure provided to an actuator of a valve coupled to a valve positioner, a drive signal is provided to a pneumatic stage of the valve positioner. The pneumatic stage is arranged to control output pressure of the valve positioner in accordance with the drive signal. A pressure measurement from a pressure sensor communicatively coupled to the valve positioner is obtained, and an abnormal pressure is detected based on the pressure measurement. In response to detecting the abnormal pressure, the drive signal is controlled so as to limit the output pressure of the valve positioner, wherein the output pressure provides control pressure to the actuator.


**15 Claims, 7 Drawing Sheets**



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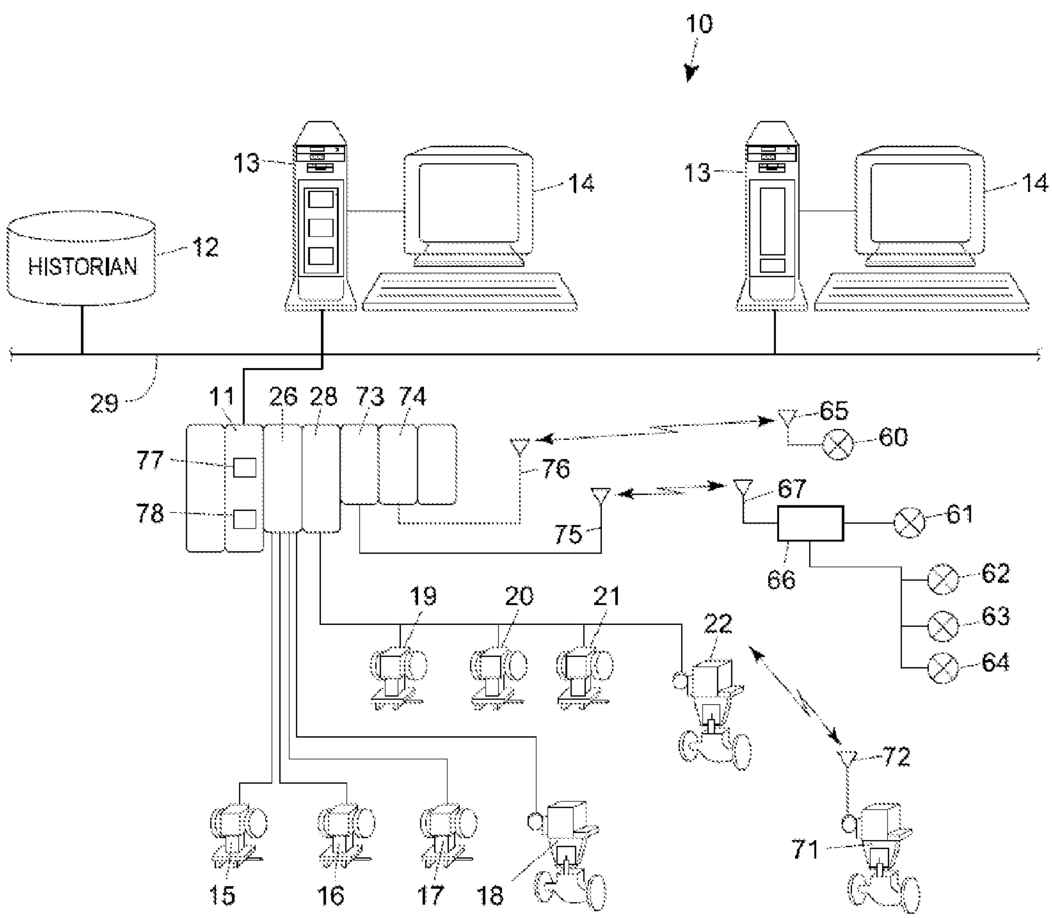

10
13
14
13
14
HISTORIAN
12
29
11
26
28
73
74
65
60
77
76
78
75
67
61
66
62
63
64
19
20
21
22
72
71
15
16
17
18

FIG. 1

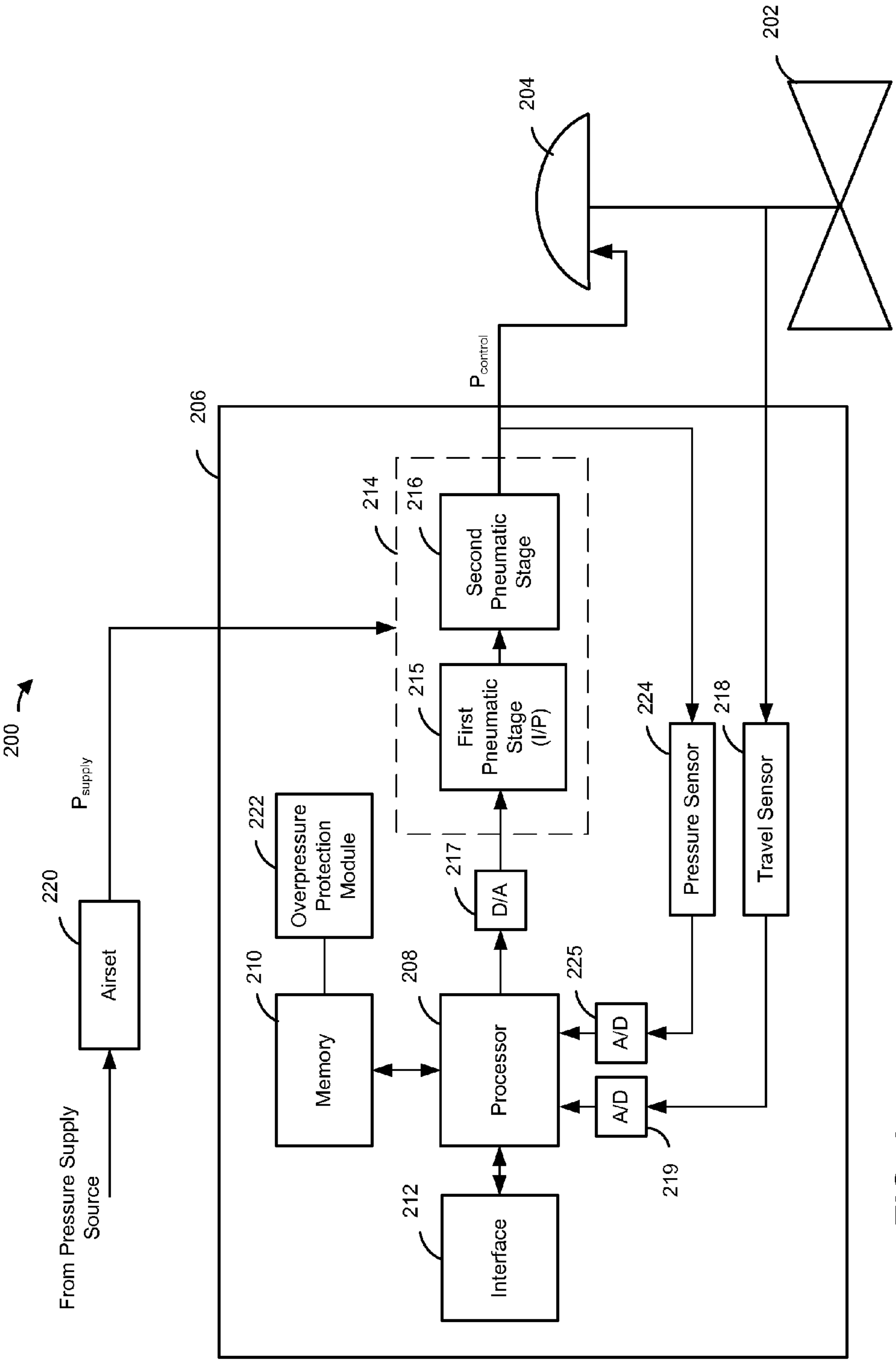

200
From Pressure Supply Source
220
Airset
$P_{supply}$
206
222
Overpressure Protection Module
210
Memory
208
Processor
212
Interface
217
D/A
214
215
First Pneumatic Stage (I/P)
216
Second Pneumatic Stage
$P_{control}$
224
Pressure Sensor
218
Travel Sensor
225
A/D
A/D
219
204
202

FIG. 2

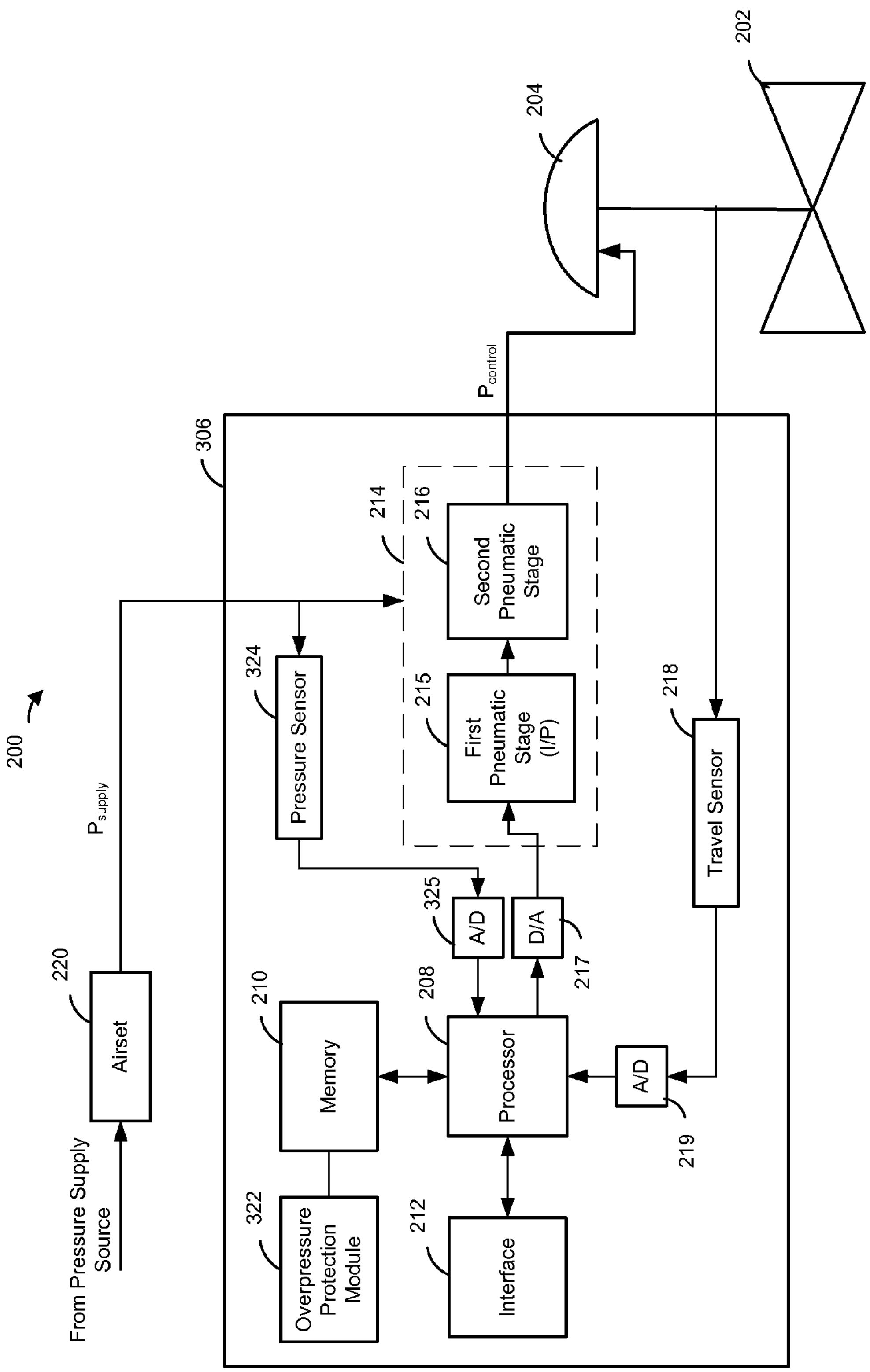

200
From Pressure Supply Source
Airset
220
$P_{supply}$
306
Pressure Sensor
324
214
First Pneumatic Stage (I/P)
215
Second Pneumatic Stage
216
$P_{control}$
204
202
Travel Sensor
218
A/D
325
D/A
217
Memory
210
Processor
208
A/D
219
Overpressure Protection Module
322
Interface
212

FIG. 3

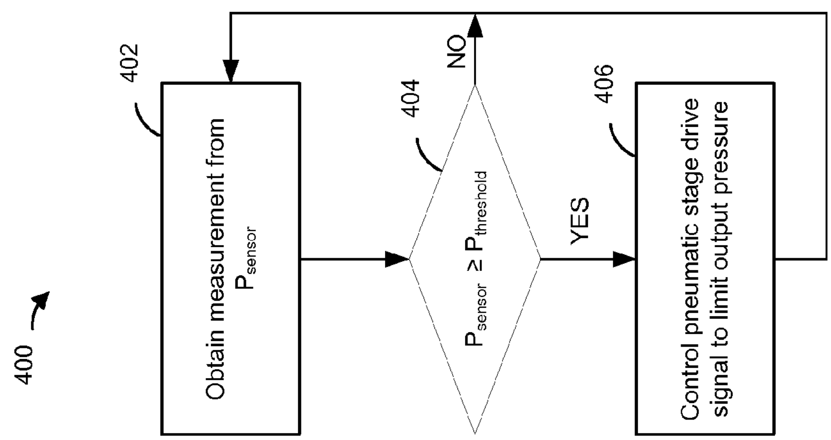

400
402
Obtain measurement from $P_{sensor}$
404
$P_{sensor} \geq P_{threshold}$
NO
YES
406
Control pneumatic stage drive signal to limit output pressure

FIG. 4

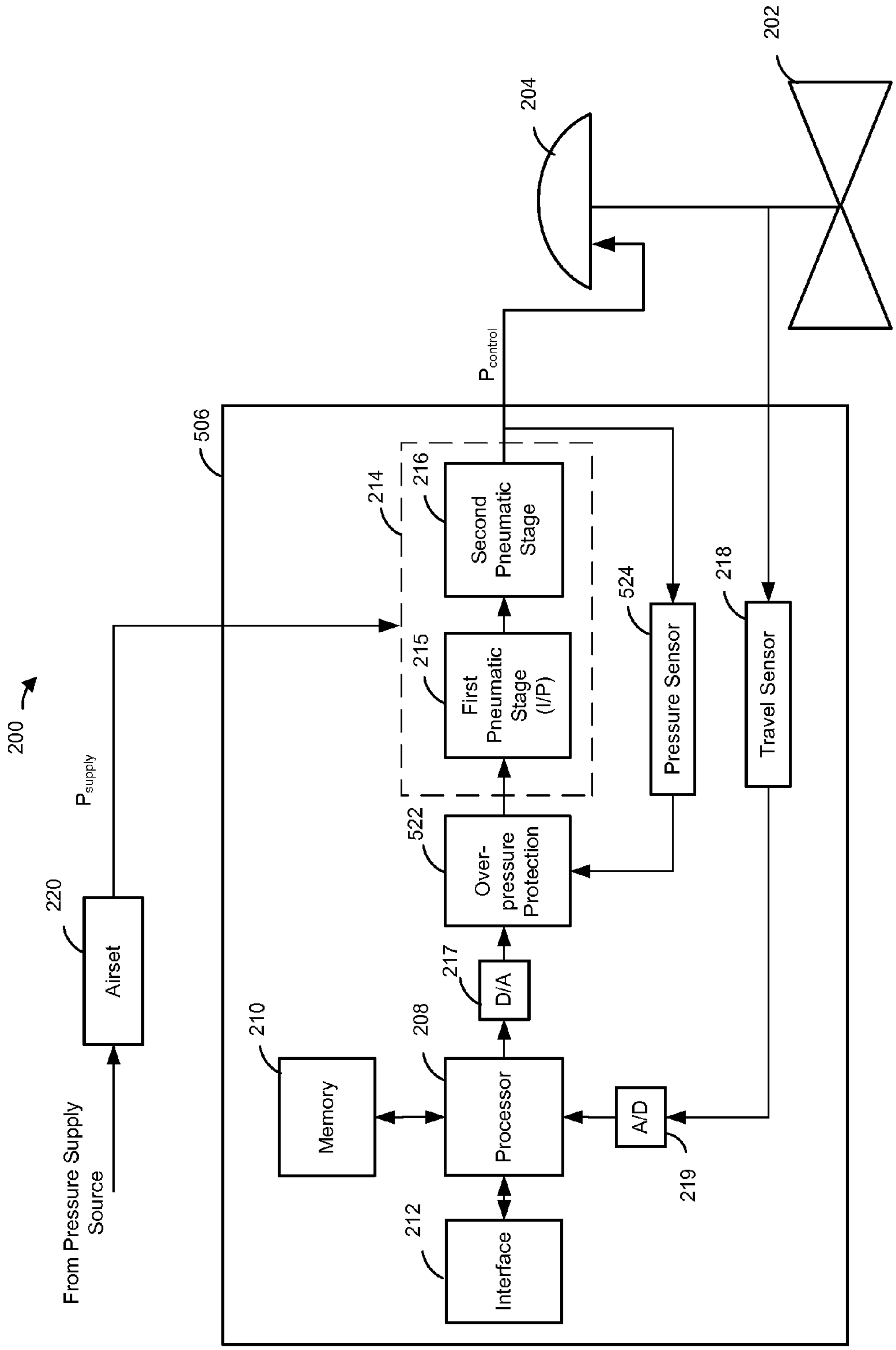

200
From Pressure Supply Source
220
Airset
$P_{supply}$
506
210
Memory
208
Processor
212
Interface
217
D/A
219
A/D
522
Over-pressure Protection
214
215
First Pneumatic Stage (I/P)
216
Second Pneumatic Stage
524
Pressure Sensor
218
Travel Sensor
$P_{control}$
204
202

FIG. 5

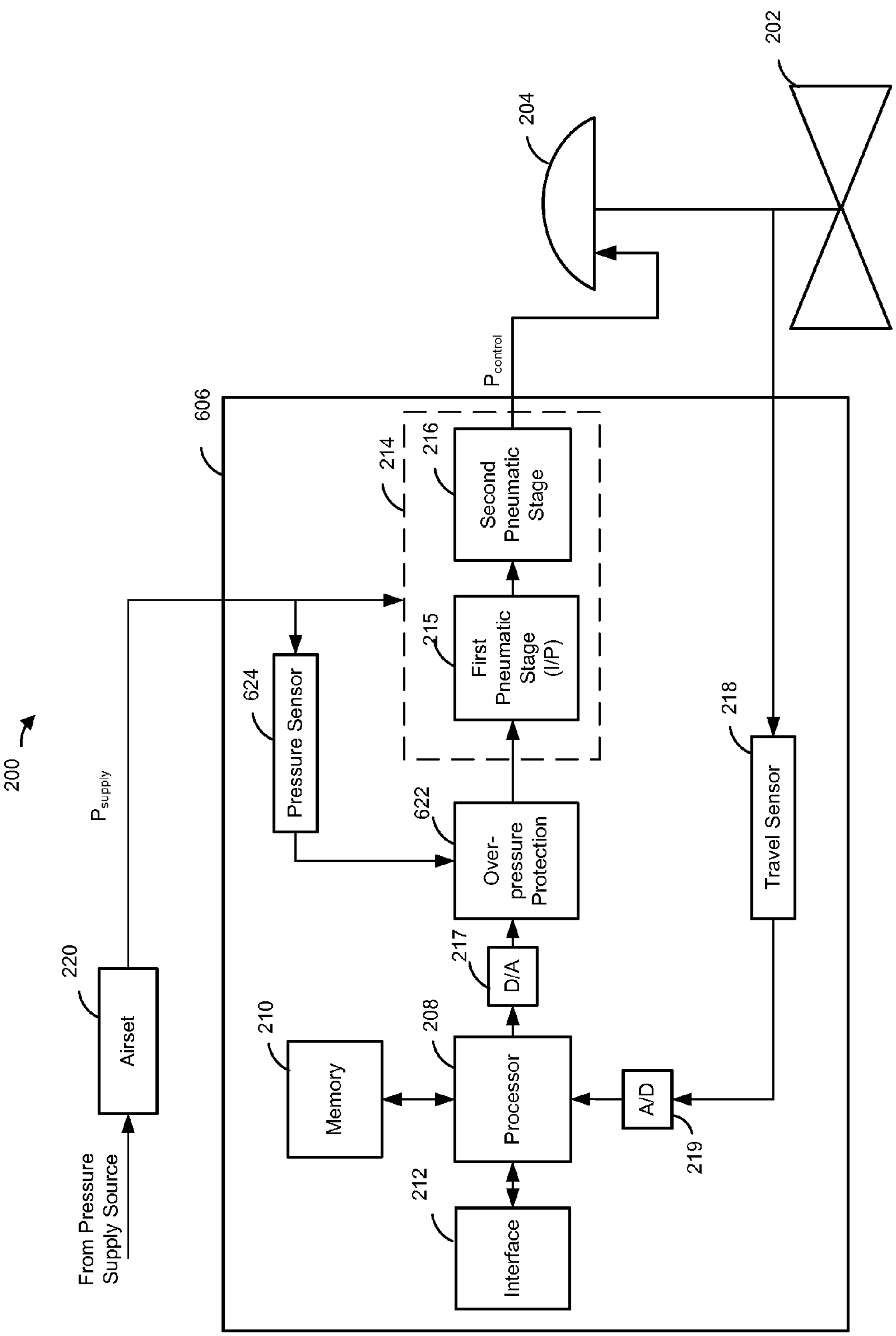
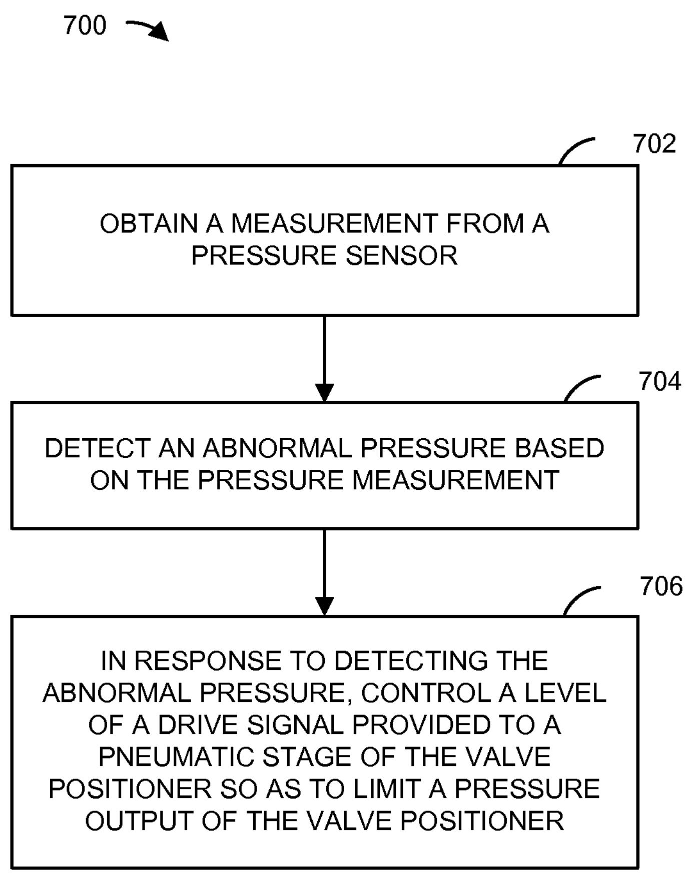

200
From Pressure Supply Source
Airset
220
$P_{supply}$
606
Memory
210
Interface
212
Processor
208
D/A
217
A/D
219
Over-pressure Protection
622
Pressure Sensor
624
First Pneumatic Stage (I/P)
215
Second Pneumatic Stage
216
214
Travel Sensor
218
$P_{control}$
204
202

FIG. 6

FIG. 7


700
702
OBTAIN A MEASUREMENT FROM A PRESSURE SENSOR
704
DETECT AN ABNORMAL PRESSURE BASED ON THE PRESSURE MEASUREMENT
706
IN RESPONSE TO DETECTING THE ABNORMAL PRESSURE, CONTROL A LEVEL OF A DRIVE SIGNAL PROVIDED TO A PNEUMATIC STAGE OF THE VALVE POSITIONER SO AS TO LIMIT A PRESSURE OUTPUT OF THE VALVE POSITIONER

# VALVE POSITIONER WITH OVERPRESSURE PROTECTION CAPABILITIES

## FIELD OF THE INVENTION

The present invention relates generally to process control systems and, more particularly, to providing overpressure protection for process control devices in process control systems.

## DESCRIPTION OF THE RELATED ART

Process control systems, such as distributed or scalable process control systems like those used in chemical, petroleum or other processes, typically include one or more process controllers communicatively coupled to one or more field devices via analog, digital, or combined analog/digital buses. The field devices, which may include, for example, control valve assemblies (e.g., control valves, actuators, valve controllers), valve positioners, switches, and transmitters (e.g., temperature, pressure and flow rate sensors), perform functions within the process such as opening or closing valves, measuring process parameters, and performing basic diagnostics. The process controller receives signals indicative of process measurements made by the field devices and/or other information pertaining to the field devices, and uses this information to execute or implement one or more control routines to generate control signals, which are sent over the buses to the field devices to control the operation of the process. Information from each of the field devices and the controller is typically made available to one or more applications executed by one or more other hardware devices, such as host or user workstations, personal computers or computing devices, to enable an operator to perform any desired function regarding the process, such as setting parameters for the process, viewing the current state of the process, modifying the operation of the process, etc.

Process control systems often employ electro-pneumatic controllers (e.g., electro-pneumatic positioners) to control process control devices operating in the process control systems (e.g., control valves, pumps, dampers, etc.). Electro-pneumatic controllers are usually configured to receive one or more control signals and convert those control signals into a pressure provided to a pneumatic actuator to cause a desired operation of the process control device coupled to the pneumatic actuator. For example, if a process control routine requires a pneumatically-actuated valve to pass a greater volume of a process fluid, the magnitude of the control signal applied to an electro-pneumatic controller associated with the valve may be increased (e.g., from 10 milliamps (mA) to 15 mA in a case where the electro-pneumatic controller is configured to receive a 4-20 mA control signal).

An electro-pneumatic controller typically includes a pneumatic module, which may include a first pneumatic stage, such as a current to pressure (I/P) transducer or voltage to pressure (E/P) transducer, and a second pneumatic stage, such as a relay. The pneumatic module typically receives a pressurized supply fluid, such as air, and modulates the pressurized supply fluid in accordance with a control signal (e.g., a current drive signal) to produce a pneumatic output signal in response to the control signal. The supply fluid is typically supplied to the electro-pneumatic controller and, more specifically, to the pneumatic stage of the electro-pneumatic controller, via a supply pressure regulator, such as an airset device or an air filter device, provided between a pressure source and a pressure supply input of the electro-pneumatic device. The pressure regulator is typically arranged to provide a suitable supply pressure that ensures that the control pressure output of the elector-pneumatic controller does not exceed a certain maximum pressure (e.g., a maximum control pressure rating of an actuator being controlled by the electro-pneumatic controller), thereby providing overpressure protection for the device being controlled.

A failure or a malfunction of the pressure regulator, however, may result in over-pressuring the device being controlled by the electro-pneumatic controller, which may damage the device being controlled (e.g. rupture an actuator) and may lead to a potentially dangerous situation within the process control system. To protect the device in case of a failure or a malfunction of the pressure regulator, a relief valve is often coupled between the control pressure output of the electro-pneumatic controller and a control pressure input of the device being controlled by the controller. The relief valve bleeds control fluid to, for example, the atmosphere when the pressure of the control fluid increases due, for example, to failure or malfunction of the pressure regulator device. As such, the relief valve provides redundant overpressure protection to the device to avoid over-pressurizing the device in case of a failure or a malfunction of the supply fluid regulator device. However, such relief valves may be expensive and inconvenient and/or may be difficult to install in process control devices.

## SUMMARY

In accordance with a first exemplary aspect, a method of limiting control pressure provided to an actuator of a valve coupled to a valve positioner. The method includes providing a drive signal to a pneumatic stage of the valve positioner, wherein the pneumatic stage is arranged to control output pressure of the valve positioner in accordance with the drive signal. The method also includes obtaining a pressure measurement from a pressure sensor communicatively coupled to the valve positioner, and detecting an abnormal pressure based on the pressure measurement. The method further includes in response to detecting the abnormal pressure, controlling the drive signal so as to limit the output pressure of the valve positioner, wherein the output pressure provides control pressure to the actuator.

In accordance with a second exemplary aspect, a process control device comprises a valve, an actuator coupled to the valve and configured to control a position of the valve, and a valve positioner coupled to the valve and to the actuator and configured to provide a control pressure to the actuator to control a position of the actuator. The valve positioner comprises a pneumatic stage arranged to receive a drive signal and to control output pressure of the valve positioner in accordance with the drive signal. The valve positioner additionally comprises an overpressure protection module configured to obtain a measurement from a pressure sensor communicatively coupled to the valve positioner, detect an abnormal pressure based on the pressure measurement, and in response to detecting the abnormal pressure, control the drive signal so as to limit the output pressure of the valve positioner, wherein the output pressure provides the control pressure to the actuator.

In accordance with a third exemplary aspect, a valve positioner coupled to a process control device comprising a valve and an actuator, the valve positioner configured to receive a control signal from a process control system and to control a pressure supplied to the actuator in accordance with the control signal. The valve positioner comprises a pneumatic stage arranged to receive a drive signal and to control output pressure of the valve positioner in accordance with the drive signal. The overpressure protection module additionally comprises an overpressure protection module configured to obtain a measurement from a pressure sensor communicatively coupled to the valve positioner, detect an abnormal pressure based on the pressure measurement, and in response to detecting the abnormal pressure, control the drive signal so as to limit the output pressure of the valve positioner, wherein the output pressure provides the control pressure to the actuator.

In further accordance with any one or more of the forgoing first, second, or third aspects, a method, a process control device and/or a valve positioner may further include any one or more of the following preferred forms.

In one preferred form, the pressure sensor is configured to sense a level of a supply pressure provided to the valve positioner.

In another preferred form, the pressure sensor is configured to sense a level of the output pressure of the valve positioner.

In another preferred form, detecting the abnormal pressure comprises comparing the pressure measurement to a predetermined threshold, and determining that the pressure is abnormal when the measured pressure exceeds the predetermined threshold.

In another preferred form, the valve positioner includes a processor and a memory, and detecting the abnormal pressure and controlling the drive signal comprises executing computer readable instructions stored in the memory.

In another preferred form the valve positioner includes a control circuit configured to receive the pressure measurement, and detecting the abnormal pressure and controlling the drive signal is performed by the control circuit.

In another preferred form the drive signal is a current signal, and controlling the drive signal comprises setting the drive signal to a value at or near zero milliamperes.

In another preferred form the drive signal is a voltage signal, and controlling the drive signal comprises setting the drive signal to a value at or near zero millivolts.

In another preferred form, the overpressure protection module is configured to compare the pressure measurement to a predetermined threshold, and determine that the pressure is abnormal when the measured pressure exceeds the predetermined threshold.

In another preferred form, the valve positioner includes a processor and a memory, and the overpressure protection module comprises computer readable instructions stored in the memory and executable by the processor.

In another preferred form, the overpressure protection module comprises a hardware control circuit.

In another preferred form, the drive signal is a current drive signal, and the overpressure detection module is configured to, in response to detecting the abnormal pressure, set the drive signal to zero to a value at or near zero milliaperes.

In another preferred form, the drive signal is a voltage drive signal, and the overpressure detection module is configured, in response to detecting the abnormal pressure, set the drive signal to a value at or near zero millivolts.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation of a process control system having one or more field devices arranged in accordance with the principles of the present disclosure.

FIG. **2** is a block diagram of an example field device arranged in accordance with an embodiment of the present disclosure.

FIG. **3** is a block diagram of an example field device arranged in accordance with another embodiment of the present disclosure. t.

FIG. **4** is a flow chart of an overpressure protection scheme according to an embodiment.

FIG. **5** is a block diagram of an example field device arranged in accordance with yet another embodiment of the present disclosure.

FIG. **6** is a block diagram of an example field device arranged in accordance with still another embodiment of the present disclosure.

FIG. **7** is a flow chart of an exemplary method for limiting control pressure provided to an actuator of a valve coupled to a valve positioner.

## DETAILED DESCRIPTION

Referring now to FIG. **1**, a process control system **10** constructed in accordance with one version of the present disclosure is depicted incorporating one or more field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, **22**, and **71** in communication with a process controller **11**, which in turn, is in communication with a data historian **12** and one or more user workstations **13**, each having a display screen **14**. So configured, the controller **11** delivers signals to and receives signals from the field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, **22**, and **71** and the workstations **13** to control the process control system.

In additional detail, the process controller **11** of the process control system **10** of the version depicted in FIG. **1** is connected via hardwired communication connections to field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, and **22** via input/output (I/O) cards **26** and **28**. The data historian **12** may be any desired type of data collection unit having any desired type of memory and any desired or known software, hardware or firmware for storing data. Moreover, while the data historian **12** is illustrated as a separate device in FIG. **1**, it may instead or in addition be part of one of the workstations **13** or another computer device, such as a server. The controller **11**, which may be, by way of example, a DeltaV™ controller sold by Emerson Process Management, is communicatively connected to the workstations **13** and to the data historian **12** via a communication network **29** which may be, for example, an Ethernet connection.

As mentioned, the controller **11** is illustrated as being communicatively connected to the field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, and **22** using a hardwired communication scheme which may include the use of any desired hardware, software and/or firmware to implement hardwired communications, including, for example, standard 4-20 mA communications, and/or any communications using any smart communication protocol such as the FOUNDATION® Fieldbus communication protocol, the HART® communication protocol, etc. The field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, and **22** may be any types of devices, such as sensors, control valve assemblies, transmitters, positioners, etc., while the I/O cards **26** and **28** may be any types of I/O devices conforming to any desired communication or controller protocol. In the embodiment illustrated in FIG. **1**, the field devices **15**, **16**, **17**, **18** are standard 4-20 mA devices that communicate over analog lines to the I/O card **26**, while the digital field devices **19**, **20**, **21**, **22** can be smart devices, such as HART® communicating devices and Fieldbus field devices, that communicate over a digital bus to the I/O card

28 using Fieldbus protocol communications. Of course, the field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, and **22** may conform to any other desired standard(s) or protocols, including any standards or protocols developed in the future.

In addition, the process control system **10** depicted in FIG. **1** includes a number of wireless field devices **60**, **61**, **62**, **63**, **64** and **71** disposed in the plant to be controlled. The field devices **60**, **61**, **62**, **63**, **64** are depicted as transmitters (e.g., process variable sensors) while the field device **71** is depicted as a control valve assembly including, for example, a control valve and an actuator. Wireless communications may be established between the controller **11** and the field devices **60**, **61**, **62**, **63**, **64** and **71** using any desired wireless communication equipment, including hardware, software, firmware, or any combination thereof now known or later developed. In the version illustrated in FIG. **1**, an antenna **65** is coupled to and is dedicated to perform wireless communications for the transmitter **60**, while a wireless router or other module **66** having an antenna **67** is coupled to collectively handle wireless communications for the transmitters **61**, **62**, **63**, and **64**. Likewise, an antenna **72** is coupled to the control valve assembly **71** to perform wireless communications for the control valve assembly **71**. The field devices or associated hardware **60**, **61**, **62**, **63**, **64**, **66** and **71** may implement protocol stack operations used by an appropriate wireless communication protocol to receive, decode, route, encode and send wireless signals via the antennas **65**, **67** and **72** to implement wireless communications between the process controller **11** and the transmitters **60**, **61**, **62**, **63**, **64** and the control valve assembly **71**.

If desired, the transmitters **60**, **61**, **62**, **63**, **64** can constitute the sole link between various process sensors (transmitters) and the process controller **11** and, as such, are relied upon to send accurate signals to the controller **11** to ensure that process performance is not compromised. The transmitters **60**, **61**, **62**, **63**, **64**, often referred to as process variable transmitters (PVTs), therefore may play a significant role in the control of the overall control process. Additionally, the control valve assembly **71** may provide measurements made by sensors within the control valve assembly **71** or may provide other data generated by or computed by the control valve assembly **71** to the controller **11** as part of its operation. Of course, as is known, the control valve assembly **71** may also receive control signals from the controller **11** to effect physical parameters, e.g., flow, within the overall process.

The process controller **11** is coupled to one or more I/O devices **73** and **74**, each connected to a respective antenna **75** and **76**, and these I/O devices and antennas **73**, **74**, **75**, **76** operate as transmitters/receivers to perform wireless communications with the wireless field devices **61**, **62**, **63**, **64** and **71** via one or more wireless communication networks. The wireless communications between the field devices (e.g., the transmitters **60**, **61**, **62**, **63**, **64** and the control valve assembly **71**) may be performed using one or more known wireless communication protocols, such as the WirelessHART® protocol, the Ember protocol, a WiFi protocol, an IEEE wireless standard, etc. Still further, the I/O devices **73** and **74** may implement protocol stack operations used by these communication protocols to receive, decode, route, encode and send wireless signals via the antennas **75** and **76** to implement wireless communications between the controller **11** and the transmitters **60**, **61**, **62**, **63**, **64** and the control valve assembly **71**.

As illustrated in FIG. **1**, the controller **11** conventionally includes a processor **77** that implements or oversees one or more process control routines (or any module, block, or sub-routine thereof) stored in a memory **78**. The process control routines stored in the memory **78** may include or be associated with control loops being implemented within the process plant. Generally speaking, and as is generally known, the process controller **11** executes one or more control routines and communicates with the field devices **15**, **16**, **17**, **18**, **19**, **20**, **21**, **22**, **60**, **61**, **62**, **63**, **64**, and **71**, the user workstations **13** and the data historian **12** to control a process in any desired manner(s).

FIG. **2** is a block diagram of an example field device **200** arranged in accordance with an embodiment of the present disclosure. The field device **200** may be incorporated within a process control system such as the example process control system **100** of FIG. **1**. With reference to FIG. **1** the field device **200** may be one of the field devices **15**-**18** which communicates with the controller **11** over an analog connection using standard 4-20 mA communication, for example. In another embodiment, the field device **200** may be one of the field devices **19**-**22** which communicates with the controller **11** over a digital bus using a digital communication protocol, such as a HART or a fieldbus protocol, or any other suitable digital communications protocol. In still another embodiment, the field device **200** may be the field device **72** which communicates with the controller **11** via a wireless connection using any suitable wireless communication protocol. In this embodiment, the field device **200** includes an antenna (not shown) included in or coupled to the field device **200** to enable wireless communication between the field device **200** and the controller **11**.

The field device **200** is illustrated in FIG. **2** as a control valve assembly having a valve **202**, an actuator **204**, and a valve positioner **206** communicatively coupled to the valve **202** and the actuator **204**. The valve **202** may be, for example, a rotary valve, a quarter-turn valve, a damper, or any other control device or apparatus. The actuator **204** may be a pneumatic actuator operatively coupled to a flow control member within the valve **202** via a valve stem, for example. The valve stem may move flow control member in a first direction (e.g., away from the valve seat) to allow fluid flow between the inlet and the outlet and in a second direction (e.g., toward the valve seat) to restrict or prevent fluid flow between the inlet and the outlet. In various embodiments, the actuator **204** may include a double-acting piston actuator, a single-acting spring return diaphragm or piston actuator, or any other suitable actuator or process control device.

In FIG. **2**, the valve positioner **206** is illustrated as a digital valve positioner having a processor **208**, a memory **210**, and an interface module **212**. Additionally, the valve positioner **206** includes a pneumatic module **214** having a first pneumatic stage **215** and a second pneumatic stage **216**. The first pneumatic stage **215** may be an electro pneumatic transducer, such as a current to pressure (I/P) transducer, a voltage to pressure (E/P) transducer, etc., that may generate an output pressure proportion to a drive signal provided to the first pneumatic stage **215**. The second pneumatic stage **216** may operate to amplify the pressure generated by the first pneumatic stage **215** to produce a pressure suitable for operation of the actuator **204**. The second pneumatic stage **216** may be, for example, a spool valve, a poppet valve, a relay, etc. The network interface **212** of the valve positioner **206** is configured to transmit and/or receive signals according to a particular communication protocol of the process control system of which the field device **200** is a part. In some embodiments, the communication protocol is a wireless mesh network protocol, such as the WirelessHART or ISA 100.11a protocol, Alternatively, the network interface

212 may support wired communications, such as standard 4-20 mA communications, and/or any communications using any smart communication protocol such as the FOUNDATION® Fieldbus communication protocol, the HART® communication protocol, etc. In some embodiments, the network interface **212** includes a transceiver (not shown). The transceiver typically includes one or more processors (also not shown) for executing instructions relating to physical (PHY) layer and other layer (e.g., medium access control (MAC) layer) tasks according to the wireless communication protocol utilized by the process control system. The network interface may be coupled to one or more antennas (not shown). Via the one or more antennas, the network interface **212** transmits and/or receives data packets according to the wireless communication protocol. The network interface **212** is preferably configured to both transmit and receive data packets.

The processor **208** may be a general purpose processor, a digital signal processor, an ASIC, field programmable gate array, or any other know or later developed processor. The processor **208** operates pursuant to instructions stored in the memory **210**. While the example field device **200** of FIG. **2** includes one processor **208**, other embodiments may include two or more processors that perform the functions of the processor **208**. The memory **210** may be a volatile memory or a non-volatile memory. The memory **210** may include one or more of a read-only memory (ROM), random-access memory (RAM), a flash memory, an electronic erasable program read-only memory (EEPROM), or other type of memory. The memory **210** may include an optical, magnetic (hard drive), or any other form of data storage device.

In operation, the processor **208** receives a command signal, such as a 4 to 20 mA command signal or a 0 to 10 V command signal, that represents a desired position of the valve **202**. The processor **208** also receives an indication of an actual position of the valve **202** provided to the processor **208** by a travel sensor **218**. The travel sensor **218** may be an analog travel sensor and may be coupled to the processor **208** via an analog to digital converter **219**. The analog to digital converter **219** may convert the analog signal produced by the travel sensor **218** to a digital signal suitable for use by the processor **208**. In another embodiment, the travel sensor **218** may be a digital sensor. For example, the travel sensor **218** may include an analog to digital converter internal to the travel sensor **218**. In this case, the analog to digital converter **219** may be omitted and the output of the travel sensor **218** may be provided directly to the processor **208**.

The processor **208** compares the desired position for the valve **202** indicated by the command signal received from the process controller with the actual position of the valve **202** indicated by the travel sensor **218**, and generates a drive signal for the pneumatic module **214** based on a difference between the desired position and the actual position of the valve **202**. The drive signal may be a current drive signal or a voltage drive signal, for example. The drive signal corresponds to an amount the valve positioner **206** is to change the position of the actuator **204** coupled to the valve **202**. The drive signal generated by the processor **208** is provided to the first pneumatic stage **215** of the pneumatic module **214** via a digital to analog converter **217**, which converts the (digital) drive signal generated by the processor **208** to an analog drive signal suitable for driving the first pneumatic stage **215**. The first pneumatic stage **215** modulates a pressurized supply fluid supplied to first pneumatic stage **215** in accordance with the drive signal to produce an output pressure that is proportional to the drive signal. The output pressure of the first pneumatic stage **215** is provided to the second pneumatic stage **216** which may amplify the pressure output of the first pneumatic stage **215** and may provide the amplified pressure to the pressure output of the valve positioner **206**. The pressure output of the valve positioner **206** is coupled to a control pressure input of the actuator **204** and provides the control pressure for the actuator **204** to control the position of the actuator **204**, thereby controlling the valve **202** to move towards the desired position for the valve **202**.

It should be noted that while the first pneumatic stage **215** is generally described herein as being a proportional I/P transducer, the first pneumatic stage **215** may instead be an on/off transducer. In this case, the pneumatic module **214** may alternate between providing the pressurized supply fluid to the control pressure input of the actuator **204**, and exhausting the pressurized supply fluid (e.g., to the atmosphere), thereby controlling the position of the actuator **204**. It is also noted that the valve positioner **206** may include other type of position control mechanisms instead of or in addition to those illustrated in FIG. **2**. Further, it should be understood that the field device **200** may be any other type of pneumatically controlled device operating within a process control system. For example, the field device **200** may be a damper, etc.

With continued reference to FIG. **2**, the supply pressure may be provided to the valve positioner **206** and, more particularly, to the first pneumatic stage **215** and the second pneumatic stage **216**, via a pressure regulator, such as an airset **220**. The airset **220** may regulate and filter a pressurized supply fluid, such as air, provided by a pressure supply source within the process control system, and may reduce the pressure provided by the pressure supply source to a pressure level suitable for use by the valve positioner **206** and by the actuator **204**. Generally, the valve positioner **206** produces output pressure by modulating the supply pressure, and the produced output pressure is typically pressurized at a level lower than the supply pressure. In some situations, the valve positioner **206** may output the full supply pressure provided to the valve positioner **206** to the actuator **204** so as to provide a maximum force to the actuator **204**, for example to force the valve **202** into a valve seat. By regulating and/or reducing the pressure provided by the pressure supply source, the pressure regulator **220** typically ensures that the output control pressure of the valve positioner **206** does not exceed a certain a maximum level, such as a maximum pressure rating of the actuator **204**, thereby providing overpressure protection for the actuator **204**. However, in a case of a failure or a malfunction of the airset **220** (e.g., when the airset **220** is stuck open and, accordingly, supplies a full, rather than reduced, supply pressure to the valve positioner **206**), the valve positioner **206** may produce a pressure output that exceeds a maximum rating of the actuator **204** or other desired maximum control pressure level for the actuator **204**, for example in a situation in which the valve positioner **206** outputs the full supply pressure of the valve positioner **206** to the actuator **204**, thereby exceeding the maximum control pressure of the actuator **204**. Exceeding the maximum pressure of the actuator **204** may over-pressurize the actuator **204**, which may damage the actuator **204** and/or may lead to a potentially dangerous situation in the process control system.

The valve positioner **206** includes an overpressure protection module **222** and a pressure sensor **224**. The overpressure module **222** generally ensures that a safe control pressure is provided to the actuator **204** even in cases of a failure or a malfunction of the airset **220**, thereby providing additional or redundant overpressure protection for the actuator **204**. In the embodiment of FIG. **2**, the overpressure protection module **222** comprises computer readable instructions stored in the memory **210**. The processor **208** is configured to execute the computer readable instructions to provide overpressure protection for the actuator **204**. The overpressure protection module **222** may operate to limit the drive signal provided to the first pneumatic stage **215** to ensure that the pressure output of the valve positioner **206** does not exceed a certain maximum value, such as the maximum pressure rating of the actuator **204**, or any other suitable value required or desired for operation of the actuator **204**.

The pressure sensor **224** is coupled to the output pressure of the valve positioner **206** and is configured to provide measurements of the output pressure of the valve positioner **206** to the processor **208**. The pressure sensor **224** may be an analog pressure sensor, in which case the output of the pressure sensor **224** may be coupled to an analog to digital converter **225**. The analog to digital converter **225** may convert the analog signal produced by the pressure sensor **224** to a digital signal suitable for use by the processor **208**. In another embodiment, the pressure sensor **224** may be a digital pressure sensor. For example, the pressure sensor **224** may include an analog to digital converter internal to the pressure sensor **224**. In this case, the analog to digital converter **225** may be omitted and the output of the pressure sensor **224** may be provided directly to the processor **208**.

The overpressure protection module **222** may monitor the pressure output of the valve positioner **206** by periodically obtaining pressure measurements provided by the pressure sensor **224**. The overpressure protection module **222** may compare the measurements obtained from the pressure sensor **224** to a predetermined threshold, and may detect an abnormal (e.g., abnormally high) pressure when the measured pressure exceeds the predetermined threshold. In response to detecting the abnormal pressure, the overpressure protection module **222** may control the level of the drive signal supplied by the processor **208** to the first pneumatic stage **215** so as to limit the output pressure of the first pneumatic stage **215** and, accordingly, limit the output pressure of the valve positioner **206**. For example, the overpressure protection module **222** may set the drive signal to a predetermined value, such as a value at or near zero milliamps in the case that the drive signal is a current drive signal, or a value at or near zero millivolts in the case that the drive signal is a voltage drive signal. Alternatively, the overpressure protection module **222** may set the drive signal to another suitable value, or may adjust the drive signal in another suitable manner, so as to reduce or limit the pressure output of the valve positioner **206**.

As yet another example, in response to detecting the abnormal pressure, the overpressure protection module **222** may operate to prevent any further adjustments of the drive signal so as to stop any further adjustments of the output pressure level of the valve positioner **206**. In this case, the output pressure level of the valve positioner **206** will stop responding to further changes in the command signal received by the valve positioner **206**. As such, the output pressure of the valve positioner **206** will remain at a level produced by the valve positioner **206** prior to detection of the abnormal pressure, such as prior to malfunction or failure of the airset **220**, in this embodiment. Alternatively, in response of detecting the abnormal pressure, the overpressure protection module **222** may operate to prevent any further increases in the level of the drive signal, while still allowing the level of the drive signal to decrease in response to receiving a command signal that results in a decrease of the dive signal level. In any event, the overpressure protection module **222**, in response to detecting the abnormal pressure, operates to ensure that the output pressure level does not increase to a level that would be unsafe and/or undesired for operation of the actuator **204**.

The components of the valve positioner **206** may be communicatively coupled as illustrated in FIG. **2** or may be coupled in any other suitable manner. Further, the valve positioner **206** may include any other components for controlling and/or providing pressure to the actuator **204** in addition to or instead of the components illustrated in FIG. **2**. Additionally or alternatively, although not shown, the valve positioner **206** may include other signal processing components such as, for example, analog-to-digital converters, digital-to-analog converters, filters (e.g., low-pass filters, high-pass filters, and digital filters), amplifiers, etc.

FIG. **3** is a block diagram of the field device **200** arranged in accordance with another embodiment of the present disclosure. In the embodiment of FIG. **3**, the valve positioner **206** of FIG. **2** is replaced by a valve positioner **306**. The valve positioner **306** is generally similar to the valve positioner **206** and includes many like-numbered elements to the valve positioner **206**. However, the valve positioner **306** is configured to detect an abnormal supply pressure provided to the valve positioner **306** rather than detecting an abnormal output pressure as is the case with the valve positioner **206**.

The valve positioner **306** includes an overpressure protection module **322** and a pressure sensor **324**. The pressure sensor **324** is coupled to a supply pressure of the valve positioner **306** and is configured to measure the level of the supply pressure provided to the valve positioner **306**. The pressure sensor **324** may provide the supply pressure measurements to the processor **208**. The pressure sensor **324** may be an analog pressure sensor, in which case the output of the pressure sensor **324** may be coupled to an analog to digital converter **325**. The analog to digital converter **325** may convert the analog signal produced by the pressure sensor **324** to a digital signal suitable for use by the processor **208**. Alternatively, the pressure sensor **324** may be a digital pressure sensor. For example, the pressure sensor **324** may include an analog to digital converter internal to the pressure sensor **324**. In this case, the analog to digital converter **325** may be omitted from the valve positioner **306** and the output of the pressure sensor **324** may be provided directly to the processor **208**.

The overpressure protection module **322** comprises computer-readable instructions stored in the memory **210** and executable by the processor **208**. The overpressure protection module **322** may be the same as or similar to the overpressure protection module **222** of FIG. **2**. The overpressure protection module **322** may operate in the same or similar manner to the overpressure protection module **222** to detect an abnormal pressure and, in response to detecting the abnormal pressure, to control the level of the drive signal provided to the first pneumatic stage **215** so as to limit the output pressure of the valve positioner **306**. In the embodiment of FIG. **3**, however, the overpressure module **322** operates by detecting the abnormal pressure based on supply pressure measurement provided by the pressure sensor **324**. For example, the overpressure protection module **322** may obtain a measurement of the supply pressure from the pressure sensor **324** and may compare the obtained supply pressure measurement to a predetermined threshold. The overpressure protection module **322** may detect an abnormal pressure when the supply pressure measurement exceeds the predetermined threshold. In response to detecting the abnormal pressure, the overpressure protection module **322** may control the level of the drive signal provided to the first pneumatic stage **215**. For example, the overpressure protection module **322** may set the drive signal to zero milliamperes, set the drive signal to zero millivolts, set the drive signal to another suitable value, prevent further adjustments of the drive signal, prevent further increases in the drive signal, etc., as described above with respect to the overpressure protection module **222** of FIG. **2**.

FIG. **4** is a flow chart of an overpressure protection scheme **400** that may be implemented by the overpressure protection module **222** of FIG. **2** or the overpressure protection module **322** of FIG. **3**. With reference to FIGS. **2** and **3**, the overpressure protection module **222** or the overpressure protection module may operate according to the scheme **400** to control the drive signal provided to the first pneumatic stage **215** so as to limit the output pressure of the valve positioner **206**. At block **402**, the overpressure protection module obtains a measurement from a pressure sensor, such as a pressure sensor coupled to the output of the valve positioner or a pressure sensor coupled to a supply pressure of the valve positioner. At blocks **404**, the overpressure protection module compares the pressure measurement obtained at block **402** to a predetermined threshold. If the measured pressure exceeds the predetermined threshold, then the scheme **400** continues at block **406** at which the overpressure protection module control the drive signal provided to the pneumatic stage of the valve positioner so as to reduce the output pressure of the valve positioner. For example, the overpressure protection module sets the drive signal to a value at or near zero milliamperes, set the drive signal at or near zero millivolts, or set the drive signal to any other suitable value. Alternatively, the overpressure protection module may prevent further adjustments of the drive signal thereby locking the drive signal at the current value of the drive signal. At yet another example, the overpressure protection module may prevent a further increase of the drive signal, while still allowing a decrease in the drive signal, or may control the drive signal in another suitable manner so as to limit the output pressure level of the valve positioner. In any event, the scheme **400** then returns to block **402**, at which the processor obtains a next measurement from the pressure sensor.

Returning to block **404**, if the comparison at block **404** indicates that the measured pressure does not exceed (e.g., is less than or equal to) the predetermined threshold, then the scheme **400** simply returns to block **402** to obtain a next measurement from the pressure sensor.

FIG. **5** is a block diagram of the field device **200** arranged in accordance with another embodiment of the present disclosure. In the embodiment of FIG. **4**, the valve positioner **206** (FIG. **2**) is replaced by a valve positioner **506**. The valve positioner **506** is generally similar to the valve positioner **206** of FIG. **2** and includes many like-numbered elements to the valve positioner **206** of FIG. **2**. In the embodiment of FIG. **5**, overpressure protection is provided by a hardware module, such as control circuit, coupled to the first pneumatic stage **215** and configured to control the drive signal provided to the first pneumatic stage **215** so as limit the output pressure of the valve positioner **506** in response to detecting an abnormal output pressure of the valve positioner **506**.

The valve positioner **506** includes an overpressure protection module **522** coupled between the processor **208** and the pneumatic module **214**. A pressure sensor **524** is coupled to the output pressure of the valve positioner **506** and is configured to measure the level of the output pressure of the valve positioner **506**. The pressure sensor **524** provides the output pressure measurements to the overpressure protection module **522**. The overpressure protection module **522** may include analog circuitry and/or digital circuitry configured to detect an abnormal output pressure of the valve positioner **506** based on output pressure measurements provided by the pressure sensor **524**. If necessary, the pressure sensor **524** may be coupled to an analog to digital converter, or alternatively to a digital to analog converter, to produce a signal suitable for use by the overpressure protection module **522**.

In response to detecting abnormal pressure based on a measurement obtained from the pressure sensor **524**, the overpressure protection module **522** operates to affect the level of the drive signal supplied to the pneumatic stage **215** so as to limit the pressure output of the valve positioner **506**. For example, the overpressure protection module **522** may, in response to detecting the abnormal pressure, set the drive signal to a level at or near zero milliamperes or at or near zero millivolts (shut off the drive signal), set the drive signal to another suitable value, prevent further adjustments of the drive signal, prevent further increases in the drive signal, etc., as described above with respect to the overpressure protection module **222** of FIG. **2**.

FIG. **6** is a block diagram of the field device **200** arranged in accordance with another embodiment of the present disclosure. In the embodiment of FIG. **6**, the valve positioner **206** (FIG. **2**) is replaced by a valve positioner **606**. The valve positioner **606** is generally similar to the valve positioner **506** of FIG. **5** and includes many like-numbered elements to the valve positioner **506** of FIG. **5**. In the embodiment of FIG. **6**, overpressure protection is provided by a hardware module, such as control circuit, coupled to the first pneumatic stage **215** and configured to control the drive signal provided to the first pneumatic stage **215** so as limit the output pressure of the valve positioner **606** in response to detecting an abnormal supply pressure of the valve positioner **606**.

The valve positioner **606** includes an overpressure protection module **622** coupled between the processor **208** and the pneumatic stage **214**. A pressure sensor **624** is coupled to the supply pressure of the valve positioner **606** and to the overpressure protection module **624**. The pressure sensor **624** is configured to measure the level of the supply pressure of the valve positioner **606** and to provide the supply pressure measurements to the overpressure protection module **622**. The overpressure protection module **622** may include analog circuitry and/or digital circuitry configured to detect an abnormal pressure based on supply pressure measurements obtained from the pressure sensor **624**. If necessary, the pressure sensor **624** may be coupled to an analog to digital converter, or alternatively to a digital to analog converter, to produce a signal suitable for use by the overpressure protection module **622**.

In response to detecting abnormal pressure based on a measurement obtained from the pressure sensor **624**, the overpressure protection module **622** controls the level of the drive signal supplied to the pneumatic stage **215** so as to limit the pressure output of the valve positioner **606**. For example, the overpressure protection module **622** may, in response to detecting the abnormal pressure, set the drive signal to a level at or near zero milliamperes or at or near zero millivolts (shut off the drive signal), set the drive signal to another suitable value, prevent further adjustments of the drive signal, prevent further increases in the drive signal, etc., as described above with respect to the overpressure protection module **222** of FIG. **2**.

Referring to FIGS. **5** and **6**, although the valve positioners **506** and **606** are illustrated as digital valve positioners, the valve positioners **506** and **606** may alternatively be analog valve positioners configured to receive an analog command signal, such as a 4-20 mA command signal, and to control a position of the valve **202** in accordance with the analog command signal. In some such embodiments, the interface **212** and/or the processor **208** and the memory **210** may be omitted from the valve positioner **506**, **606**. In such cases, the analog command signal may be provided to the pneumatic stage **214** via the overpressure protection module **522**, **622** to provide overpressure protection for the actuator **204**.

In various embodiments described above, the overpressure protection modules **222**, **322**, **522**, **622** may be configured to, in response to detecting an abnormal pressure (e.g., supply input abnormal pressure or control pressure output abnormal pressure), cause a signal indicative of the abnormal pressure to be sent to a controller and/or a host device within the process control system of which the field device **200** is a part, such as to the process controller **11** of FIG. **1**. Transmitting a signal indicative of the detected abnormal pressure to a controller or a host device within the process control system may indicate to an operator monitoring the process control system that the airset **220** has failed, and may allow the operator to take an appropriate action, such as repairing or replacing the airset, shutting down the field device **200**, shutting down the process control system (or a portion thereof) that includes the field device **200**, etc.

FIG. **7** is a flow chart of an exemplary method **700** for limiting control pressure provided to an actuator of a valve coupled to a valve positioner. In various embodiments, the method **700** is implemented by the field device **200** of FIG. **2**. In an embodiment, the method **700** is implemented by the processor **208** in accordance with the overpressure protection module **222** stored in the memory **210**. In another embodiment, the method **700** is implemented using a hardware overpressure protection module coupled to a current drive input of a pneumatic stage of the valve positioner. In other embodiments, the method **700** is implemented at least partially using other components of the field device **200** or is implemented by devices other than the field device **200**.

At block **702**, a pressure measurement is obtained. In an embodiment, the pressure measurement is obtained from a pressure sensor coupled to a control pressure output of the valve positioner. In another embodiment, the pressure measurement is obtained from a pressure sensor coupled to a supply pressure input of the valve positioner. At block **704**, an abnormal pressure is detected based on the pressure measurement obtained at block **702**. For example, the pressure measurement is compared to a predetermined threshold, and the abnormal pressure is detected when the pressure measurement obtained at block **702** exceeds the predetermined threshold. Then, at block **706**, in response to detecting the abnormal pressure at block **704**, a drive signal provided to a pneumatic stage of the valve positioner is controlled so as to limit the output control pressure of the valve positioner. For example, the block **706** may include setting the drive signal to zero milliamperes, setting the drive signal to zero millivolts, setting the drive signal to another suitable value, preventing further adjustments of the drive signal, preventing further increases in the drive signal, etc., as described above, in various contemplated embodiments.

While various functions and/or systems of field devices have been described herein as "modules," "components," or "function blocks," it is noted that these terms are not limited to single, integrated units. Moreover, while the present invention has been described with reference to specific examples, those examples are intended to be illustrative only, and are not intended to limit the invention. It will be apparent to those of ordinary skill in the art that changes, additions or deletions may be made to the disclosed embodiments without departing from the spirit and scope of the invention. For example, one or more portions of methods described above may be performed in a different order (or concurrently) and still achieve desirable results.

The invention claimed is:

**1**. A process control device, comprising:

a valve;

an actuator coupled to the valve and configured to control a position of the valve; and

a valve positioner coupled to the valve and to the actuator and configured to provide a control pressure to the actuator to control a position of the actuator, the valve positioner comprising:

a pneumatic stage arranged to receive a drive signal and to control output pressure of the valve positioner in accordance with the drive signal, and

an overpressure protection module configured to:

obtain a measurement from a pressure sensor communicatively coupled to the valve positioner;

detect an abnormal pressure based on the pressure measurement; and

in response to detecting the abnormal pressure, control the drive signal so as to limit the output pressure of the valve positioner, wherein the output pressure provides the control pressure to the actuator.

**2**. The process control device of claim **1**, wherein the pressure sensor is configured to measure a level of a supply pressure provided to the valve positioner.

**3**. The process control device of claim **1**, wherein the pressure sensor is configured to measure a level of the pressure output by the valve positioner.

**4**. The process control device of claim **1**, wherein the overpressure protection module is configured to:

compare the pressure measurement to a predetermined threshold; and

determine that the pressure is abnormal when the measured pressure exceeds the predetermined threshold.

**5**. The process control device of claim **1**, wherein the valve positioner includes a processor and a memory, and wherein the overpressure protection module comprises computer readable instructions stored in the memory and executable by the processor.

**6**. The process control device of claim **1**, wherein the overpressure protection module comprises a hardware control circuit.

**7**. The process control device of claim **1**, wherein the drive signal is a current drive signal, and wherein the overpressure detection module is configured to, in response to detecting the abnormal pressure, set the drive signal to a value at or near zero milliamperes.

**8**. The process control device of claim **1**, wherein the drive signal is a voltage drive signal, and wherein the overpressure detection module is configured, in response to detecting the abnormal pressure, set the drive signal to a value at or near zero millivolts.

**9**. A valve positioner coupled to a process control device comprising a valve and an actuator, the valve positioner configured to receive a control signal from a process control system and to control a pressure supplied to the actuator in accordance with the control signal, the valve positioner comprising:

a pneumatic stage arranged to receive a drive signal and to control output pressure of the valve positioner in accordance with the drive signal, and

an overpressure protection module configured to:

obtain a measurement from a pressure sensor communicatively coupled to the valve positioner;

detect an abnormal pressure based on the pressure measurement; and

in response to detecting the abnormal pressure, control the drive signal so as to limit the output pressure of the valve positioner, wherein the output pressure provides the control pressure to the actuator.

**10**. The valve positioner of claim **9**, wherein the pressure sensor configured to measure a level of a supply pressure provided to the valve positioner.

**11**. The valve positioner of claim **9**, wherein the pressure sensor is configured to measure a level of the pressure output of the valve positioner.

**12**. The valve positioner of claim **9**, wherein the valve positioner includes a processor and a memory, and the overpressure protection module comprises computer readable instructions stored in the memory and executable by the processor.

**13**. The valve positioner of claim **9**, wherein the overpressure protection module comprises a hardware control circuit.

**14**. The valve positioner of claim **9**, wherein the drive signal is a current drive signal, and wherein the overpressure detection module is configured to, in response to detecting the abnormal pressure, set the drive signal to a value at or near zero milliamperes.

**15**. The valve positioner of claim **9**, wherein the drive signal is a voltage drive signal, and wherein the overpressure detection module is configured to, in response to detecting the abnormal pressure, set the drive signal to a value at or near zero millivolts.

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